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MARCH 1948

UNITED STATES
DEPARTMENT OF THE INTERIOR
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MINING METHODS AT THE VULCAN IRON MINE
SAN BERNARDINO COUNTY, CALIF.

BY

C. L. SEVERY

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MINING METHODS AT THE VULCAN IRON MINE, SAN BERNARDINO COUNTY, CALIF.[1]

By C. L. Severy[2]

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7437."

[2] Mining engineer, Reno Branch, Mining Division, Bureau of Mines, U. S. Department of the Interior.

SUMMARY

The Vulcan mine, which is the only large-scale open-pit iron mine in California, furnishes the blast-furnace feed for the Kaiser Co., Inc., steel plant at Fontana, Calif. It lies in the Mojave Desert, San Bernardino County, Calif., at an altitude of 4,000 feet and 9 miles from Kelso, a station on the Union Pacific Railroad 178 miles by rail from Fontana.

The deposit is an irregular, mushroom shaped replacement of limestone by magnetite and hematite along a fault contact with quartz monzonite. On the surface, the ore body was 700 feet long by 325 feet wide, ovular in shape, and striking roughly east and west. The ore extends to a maximum depth of 900 feet as determined by diamond drilling.

Exploration consisted of 482 feet of adits and 49 diamond-drill holes having depths 18 to 897 feet and totaling 11,672 feet.

As laid out, the open pit has seven benches, the top one 60 feet, one 50 feet, and five 40 feet in height. Six of these have been opened to the present 3,790-foot bench. Mining is confined to one shift per day, and production averages 2,500 tons. Churn drills, wagon drills, and jackhammers are used for drilling various depths of blast holes.

Open-pit mining with 2½-cubic-yard Diesel-powered shovels started December 12, 1942, and to January 1, 1947, 2,100,000 tons[3] of ore had been mined, leaving a developed reserve of 400,000 tons to the 3,750-foot bench, which will be the bottom of the pit as planned. All stripping for mining to this depth has been completed. There remain 2,500,000 tons of proven but not developed high-sulfur ore below the proposed pit bottom. The calculated grade for the indicated 5,000,000 ton ore reserves was 52.23 percent iron, 0.058 percent phosphorus, 5.22 percent silica, and 1.62 percent sulfur.

From the pit the ore is trucked in Euclid 10 cubic yard dump trucks to the crushing plant, where the ore is reduced by an electrically driven 42 by 48-inch jaw crusher to minus 8-inch size and stocked by conveyor belt on a 6,000-ton storage pile. Fifteen cubic yards Kenworth, semitrailer, Diesel-powered, end-dump trucks haul the ore from the storage pile 9 miles to Kelso, where it is either loaded into cars for shipment to Fontana or stock-piled. This hauling is contracted.

At Fontana the ore is crushed to 1-3/4 inches and sized through screens, the minus 1/2-inch going to the sintering plant and the oversize to the bedding pile, from whence the ore is drawn off, sampled, and weighed for blast-furnace feed. From 50 to 70 percent of the Vulcan ore is sintered.

Besides the crushing unit, the surface plant at the mine consists of an office, warehouse, garage, machine shop, power plant, dormitories, dining room, cook house, and superintendent's house. From 80 to 85 men are employed

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[3] All tonnages are short tons unless otherwise stated.

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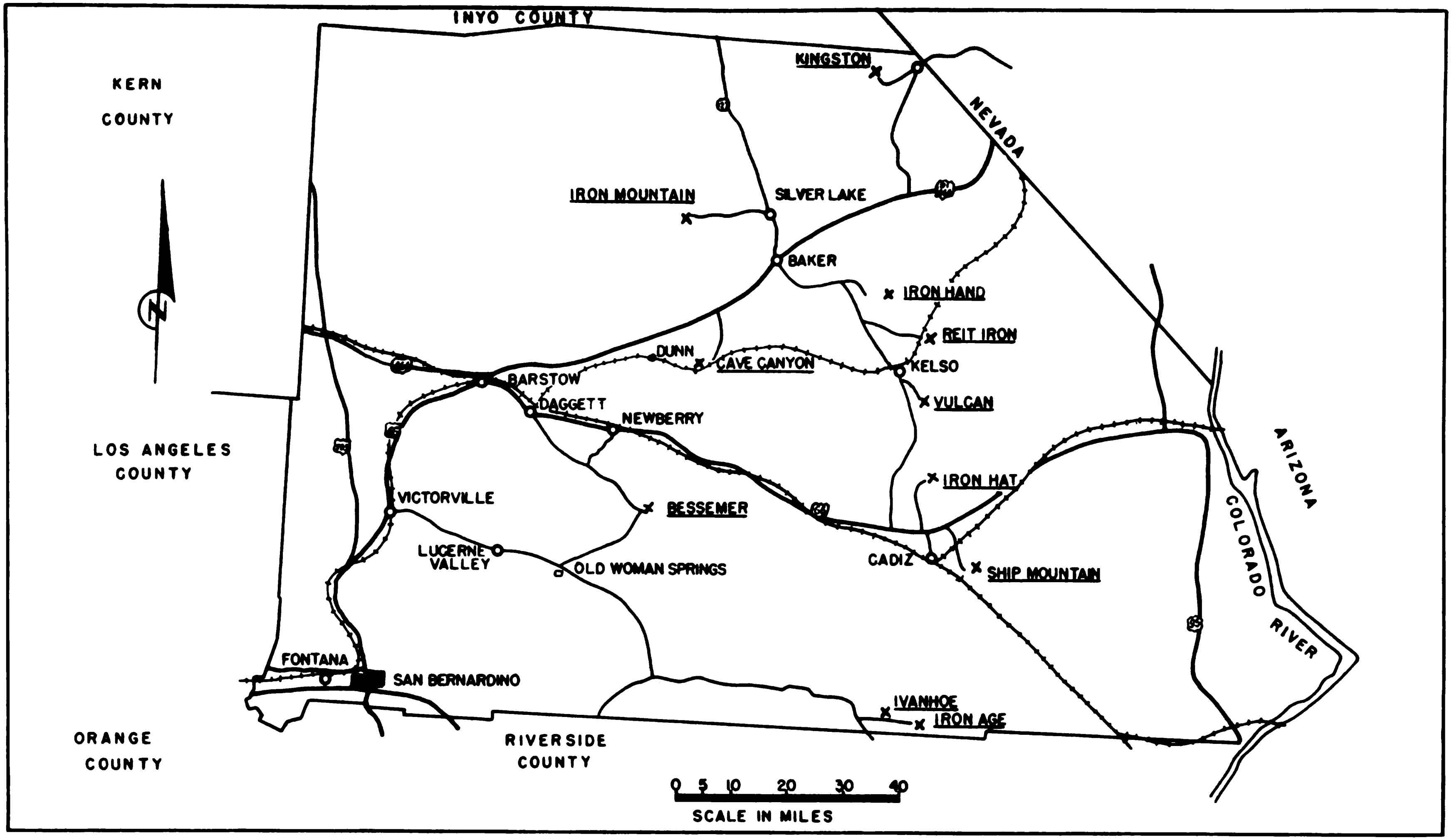

FIGURE I. IRON DEPOSITS OF SAN BERNARDINO COUNTY, CALIFORNIA

at the mine and 12 to 14 men on the contract truck haul. A company-owned trailer court at Kelso accommodates 20 families, and space is provided for 10 private trailers.

INTRODUCTION

One of the functions of the Bureau of Mines is to collect and publish data on mining operations that may be of interest and useful to the mining industry. This paper covers operations at the Vulcan iron mine, which is the largest producer of iron ore on the Pacific coast, and was compiled by the Mining Division, of which Lowell B. Moon is chief.

Acknowledgment is made to Spangler Ricker, supervising engineer, California Field Office, and to A. C. Johnson, chief of the Reno Branch, Mining Division for their constructive criticism of the report.

For their courtesy and assistance in furnishing the data upon which the report is based, special acknowledgment is made to the following members of the staff of Kaiser Co., Inc.: A. B. Ordway, vice president and general manager, Fontana Steel Plant; T. M. Price, vice president; Ken B. Powell, mining engineer; John Tillia and Charles Severy, geologists.

LOCATION AND PHYSICAL FEATURES

Figure 1 shows the location of the mine in respect to other known iron occurrences of San Bernardino County and to the Fontana blast furnace. It lies in the SW$\frac{1}{4}$ of sec. 25, T. 10 N., R. 13 E., San Bernardino Meridian, and is 9 miles southeast of Kelso, in the central part of the Mojave Desert. Kelso is a station on the Union Pacific Railroad and the rail distance from there to Fontana is 178 miles.

The deposit occupies a ridge on the west slope of the Providence Mountains, which rise to an altitude of 5,000 to 6,000 feet northeast of the mine. Altitude at the ore outcrop ranges from 3,900 to 4,100 feet, and at Kelso it is 2,150 feet.

Typical of the Mojave Desert, the general area is made up of steep mountains surrounded by long alluvial fans, which extend to the valley floors. The temperature ranges from 105 degrees in summer to below freezing during the winter months. Owing to the altitude at the mine, the summer nights are usually comfortable. The annual rainfall ranges from 1 to 6 inches and is derived largely from thunderstorms.

Two sources of water are available to the mine: The Goldstone spring and the Cornfield or Union Pacific spring. The Goldstone spring furnished 1 gallon per minute by gravity through 1$\frac{1}{4}$ miles of 1-inch pipeline, but this line is no longer in use. The normal flow of 150 gallons per minute from the Cornfield spring is being stored in a million-gallon reservoir 1 mile south of Kelso, for emergency use by the Union Pacific Railroad, from whom the Vulcan mine now purchases its entire water supply. The water is piped 3.4 miles from the reservoir to the ore-haulage road, from whence it is trucked about 5 miles to the mines.

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HISTORY

The Vulcan iron deposit was located by Charles Colcock Jones in 1907, and the first application for patent survey was made on July 5, 1907. Five mining claims and a millsite were patented subsequently, and in 1912 ten holes were diamond drilled into the deposit, and 80 feet of adit was driven.

During the war, when the shortage of ship's plates became acute, the Kaiser Co., Inc., Iron and Steel Division, was organized to build a 1,200-ton daily capacity blast furnace and steel mill on the Pacific coast. From the many iron deposits examined, the Vulcan was chosen as a quick and adequate source of iron-ore supply for the first few years of operations. Consequently, it was purchased in June 1942, and additional claims were located for water rights and surface installations.

Further diamond drilling was done from May to September 1942. A blacktop road was constructed from Kelso to the mine. A camp to accommodate 100 men was erected; crushing equipment was installed; and mining began on December 12, 1942. The first pig iron was cast at Fontana on December 31, 1942. Since that time the mine has been in continuous operation with the exception of one 6-month period, October 1945 to March 1946, inclusive, when mining was suspended to reduce inventories of stock-piled ore.

GEOLOGY

The following paragraphs on geology are quoted from the report of Charles Severy, geologist for Kaiser Co., Inc.:

> Geologically, this region is composed of three main rocks: ancient sedimentary deposits, which have since been more or less metamorphosed; intrusions of acid igneous rocks; and later intrusions and flows of rhyolites.
>
> The oldest sedimentary rocks in the region are Cambrian limestones and shales, which have since been metamorphosed to marbles and phyllites. Uncomformably above the Cambrian rocks lie other Paleozoic and Mesozoic marine meta-sediments. Faulted against these sedimentaries is a large mass of quartz monzonite, undoubtedly intruded at depth and later brought to its present position by faulting. This igneous mass, probably of Jurassic age, lies to the west and southwest of the deposit. Tertiary intrusive rhyolites have intruded the sedimentary series on the north and northeast, whereas small rhyolitic flows are present immediately to the north of the deposit.
>
> The Vulcan iron deposit is an irregular, mushroom-shaped replacement of limestone by magnetite and hematite along a fault contact with a quartz monzonite. On the surface the body is 700 feet long by 325 feet wide, maximum dimensions, and it is ovular in shape, striking roughly east-west. It occupies two hillsides, being transected by a dry wash. The larger part of the ore body lies on the eastern slope, the smaller portion on the west, where it is terminated

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by a fault. There is no overburden on the deposit. In three dimensions, the deposit has a mushroom shape, with the north, east, and south ore contacts with limestone dipping inward toward the middle of the deposit at angles of 50 to 85 degrees. In the center of the deposit, as explored by diamond-drill holes "A" and "B", the ore extends to a depth of around 900 feet, simulating a stem or pipe. On the west, the ore is terminated by a high-angle reverse fault striking N. 60° W. and dipping 70 degrees to the west, which brings the iron and limestone against the quartz monzonite. No ore is found in the monzonite or in commercial quantities at any other point in the limestone along the fault.

The relation of mineralization of the faulting is somewhat obscure, but it is certain that movement has occurred above the fault subsequent to the mineralization. Proof is found in slickensided iron ore along the fault zone and that no iron is found in the monzonite, which would be expected even if conditions for replacement were favorable. There are two possibilities as to the sequence of faulting and mineralization. One is that the replacement by the ore occurred in the limestone on both sides of the fault. Later movement and erosion removed all traces of the ore on the west and brought the monzonite against the terminated ore body. The other is that the replacement occurred, with the monzonite on the one side being relatively unreplaced, with some later movement along the fault plane.

CHARACTER OF ORE

Three main types of ore are found in this deposit:

1. A highly oxidized mixture of hematite and limonite.
2. A dark-gray magnetite with a small amount of hematite.
3. A blue-black magnetite-hematite ore with a high lime content.

The first type of ore is encountered in the east drift from the portal to approximately 150 feet, and in the diamond-drill holes to an average depth of 50 feet. In general, it is a soft, fractured ore composed largely of hematite and limonite stain, with some black magnetite. Calcite, often iron-stained, in the form of seams, encrustations, and disseminations is abundant and forms the bulk of the gangue material. Greenish serpentine occurs as small inclusions and disseminations. Only occasional pyrite is found.

The second type of ore is found with depth in the drill holes and in the east drift beyond 150 feet and extending almost to the contact. It is a hard, fine to medium-grained, gray-black magnetite with small amounts of hematite, which decreases with depth. Occasionally, subhedral to euhedral crystals of magnetite are found associated with serpentine. Pyrite occurs as disseminations, scattered grains, and seams through the ore and in general increases with depth. Often the pyrite is associated with calcite as subhedral

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crystals. Calcite, up to 5 percent, occurs as stringers, inclusions, and small veinlets cutting the ore at random. Serpentine is the most abundant waste material, occurring as inclusions, wide bands up to 3 feet in width, and as disseminations through most of the ore body. It varies in color from a white or buff through green to a dark blue, and is often mottled. It is commonly soft, although some sections are porcelaneous in character.

The third type of ore is a blue-black magnetite-hematite that has a high lime content. The lime occurs as calcite thoroughly disseminated through the ore. Pyrite occurs as small grains throughout this type of ore, which is found on the western side of the deposit adjacent to the fault and close to the contact in the east drift.

The average specific gravity of the Vulcan ores, including waste sections, as determined from a systematic examination of the drill cores and drift samples is 3,85.

The chemical composition of the ore was determined from assays of the cores and sludes from diamond-drill holes, cut samples from the drifts, and surface samples taken at 50-foot intervals over the entire outcrop. Values were calculated by dividing the proposed pit into 13 mining blocks, and the combined results were as follows:

Entire ore body

				Percent					
	Fe	P	Mn	SiO_2	Al_2O_3	CaO	MgO	S	TiO_2
Waste included...	52.23	0.058	0.08	5.22	1.85	4.70	5.17	1.62	0.20
Waste excluded...	54.99	0.052	0.09	4.69	1.69	4.40	4.30	1.66	

Minable ore body

				Percent					
	Fe	P	Mn	SiO_2	Al_2O_3	CaO	MgO	S	TiO_2
Waste included...	50.69	0.063	0.11	3.89	1.45	6.30	5.18	1.19	0.20
Waste excluded...	55.16	0.06	0.10	3.40	1.56	5.33	4.10	0.96	

Minable ore is that which can be mined by open-pit methods. Owing to its high phosphorus content, it is of the non-Bessemer or basic type. The most detrimental element is the sulfur in the pyrite, which has not set pattern of distribution but in general increases with depth. The silica content is consistently low.

EXPLORATION

Exploration was done principally by the driamond drilling of 49 holes ranging in depth from 18 to 897 feet and totaling 11,672 feet. In addition, 482 feet of adit was driven.

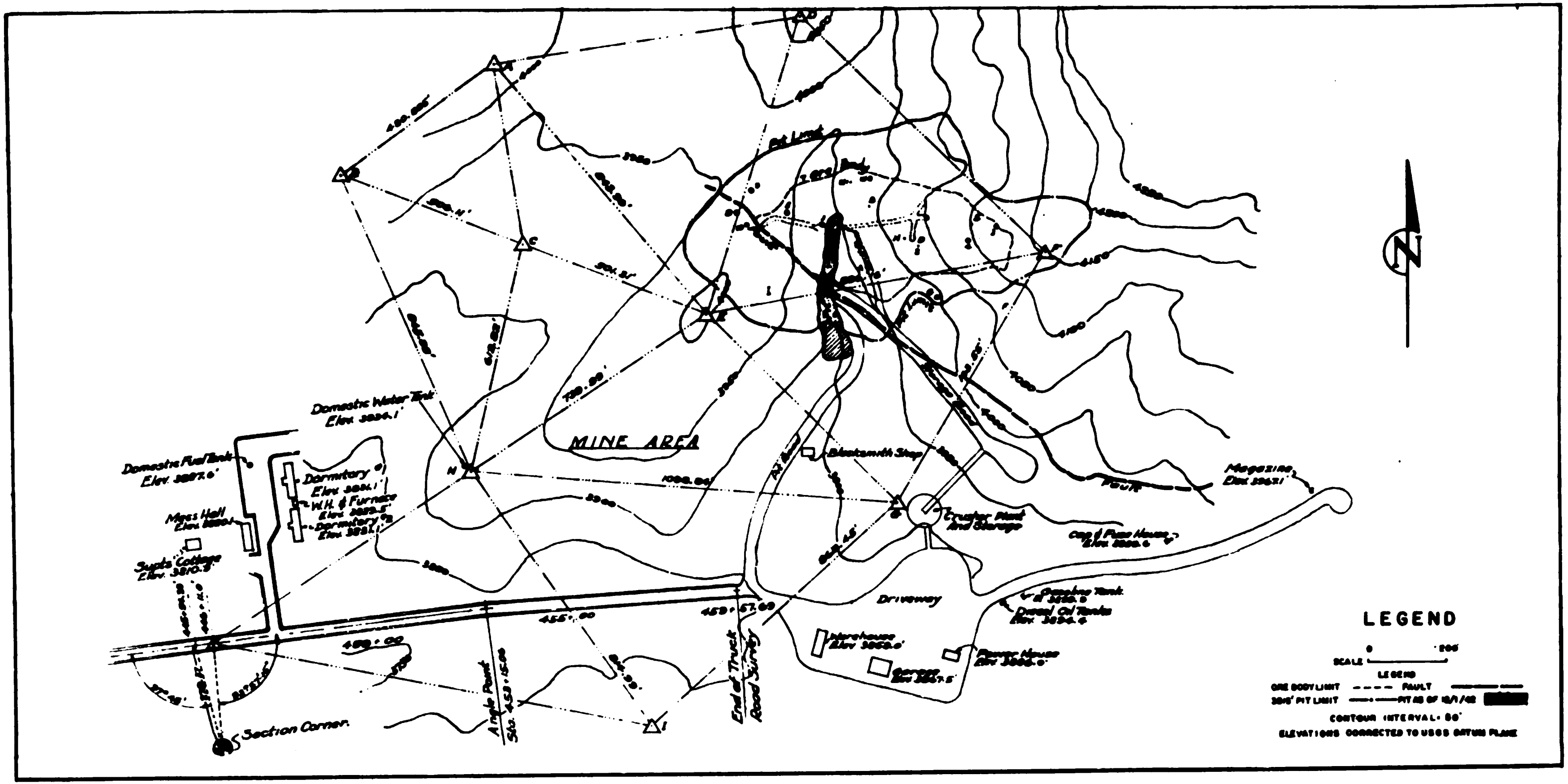
MINE AREA
Pit Limit
Ore Body
Fault
Domestic Water Tank Elev. 3834.1'
Domestic Fuel Tank Elev. 3827.6'
Dormitory #1 Elev. 3821.1'
W.H. & Furnace Elev. 3832.5'
Dormitory #2 Elev. 3831.1'
Mess Hall Elev. 3820.1
Supts. Cottage Elev. 3810.3'
Section Corner.
Angle Point Sta. 453+15.06
End of Truck Road Survey
455+00
453+57.69
459+00
Blacksmith Shop
Crusher Plant And Storage
Cap & Fuse House Elev. 3880.6
Magazine Elev. 3962.1'
Gasoline Tank El. 3858.0
Diesel Oil Tanks Elev. 3854.4
Driveway
Warehouse Elev. 3859.0'
Garage Elev. 3847.5'
Power House Elev. 3868.0'
N
LEGEND
SCALE 0 200
LEGEND
ORE BODY LIMIT
FAULT
3815' PIT LIMIT
PIT AS OF 12/1/42
CONTOUR INTERVAL: 50'
ELEVATIONS CORRECTED TO U.S.G.S. DATUM PLANE

FIGURE 2. VULCAN IRON MINE CULTURE MAP, SAN BERNARDINO COUNTY, CALIFORNIA.

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The first work was done some 30 years ago. At that time, 10 holes ranging in depth from 18 to 350 feet and totaling 1,793 feet were drilled by the Continental Drilling Co. of Los Angeles. Also, prior to the acquisition of the property by the present owners, an adit was driven from the dry wash westward under the outcrop for 80 feet.

Kaiser Co., Inc., diamond drilled nine holes between May and September 1942 for a total of 3,111 feet and extended the east adit for a total length of 252 feet. At a point 210 feet in from the portal of the adit, two crosscuts were run, one northeast for 45 feet and the other southward for 50 feet. On the west side of the dry wash another adit was driven 135 feet westerly until it cut across the fault and penetrated the country rock.

During 1944, 30 additional holes were diamond-drilled with company-owned drills. These ranged in depth from 71 to 445 feet and totaled 6,768 feet. Records show an over-all core recovery of 76.4 percent on this drilling.

ORE RESERVES

The extent of the ore body, tonnages, and grade were determined from the results obtained from the diamond drilling, and the pit-layout mining plan was based upon these determinations. In estimating the tonnage, six longitudinal sections and 15 cross sections were drawn on a 50-foot grid, and a factor of 9.3 cubic feet per long ton was used. In establishing the grade of the ore, the core and sludge assays from the diamond drill were adjusted according to relative volume by use of the Longyear factors. Where core recovery was 100 percent, the core analysis alone was used.

Reserves classed as minable ore include only that portion of the ore body that can be extracted economically by open-pit methods of mining. The total ore developed piror to the 1944 drilling was 5,050,000 tons. It extended to a maximum depth of 825 feet below the lowest point of the surface outcrop. The 1944 drilling indicated ore to the north of the pit but did not determine the limits in that direction or in depth.

According to the original plan, mining operations would terminate on the 3,675-foot pit level, but this plan was later revised, and mining by the open-pit method will be carried down to the 3,750-foot level. The estimate of the ore above the 3,750-foot level was 2,500,000 tons, of which 2,100,000 tons had been mined to January 1, 1947. There will remain, therefore, over 2,500,000 tons of high-sulfur-content ore that has been diamond drilled but not yet developed and that cannot be mined in the present pit set-up without additional stripping. It is doubtful whether these reserves will be mined in the near future owing to the excessive amount of waste to be moved in order to enlarge the pit for deeper mining.

DEVELOPMENT AND OPERATIONS

Figure 2 shows the surface area at the beginning of mining operations.[4] A pit was started at the lowest level of the ore outcrop in the dry wash.

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[4] Map from Geological Report by Charles Severy.

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There was no overburden on the ore, but large quantities of waste have been stripped, so that a pit slope of 1:1 could be maintained in the wall rock around the edges. The pit slope in the ore is 1/2:1. Waste is dumped on the southwest and west sides, where there is unlimited dump room. This is shown in figure 4.

The pit eventually will have seven benches, the top one 60 feet, one 50 feet, and five 40 feet in height. Faces of the top bench, which is at an altitude of 4,000 feet, extended to the upper limits of the outcrop, which on the east side reached an altitude of 4,060 feet. The lowest pit bench is now on the 3,790-foot level, and one more will be opened. The width of the benches varies with their location in the pit. When abandoned, a remnant of each bench is left to catch any falling rocks and to leave the over-all slope 1/2:1.

Figure 3 shows the pit plan.[5] The pit is stadium-shaped, and the axis is N. 44° W. At the top it is 1,000 feet long and 600 feet wide.

Normal rate of production is 2,200 to 2,800 tons per day of one 8-hour shift, but 3,500 tons has been produced in one day. Mining started December 10, 1942, and proceeded at varying rates as follows: Ore was mined continuously on a single-shift daily basis to December 31, 1944, at which time mining was discontinued and stripping was done on a two-shift daily basis until May 31, 1945. During stripping, ore requirements were met from the stock pile at Kelso, where 250,000 tons had accumulated during the 2-year mining period. Ore was again mined from June 1, 1945, to September 30, 1945, when mining operations were suspended until April 1, 1946 in order to reduce inventories of stock pile ore.

The Vulcan mine furnished all of the iron ore used at Fontana from December 1942 to January 1, 1945, after which time and until January 31, 1946, about 40 percent of the blast-furnace feed was ore low in sulfur purchased in Utah. Since that period, the Fontana plant has been operating entirely on Vulcan ore. For several months the plant has been operating on a curtailed basis, but production is being stepped up to 1,200 tons of hot metal, and this will require 2,400 tons of ore per day.

From the beginning of operations to January 1, 1947, a total of 2,100,000 tons has been mined, and 1,855,400 tons of this has been shipped to Fontana. This ore contained 52 to 55 percent iron, and the sulfur content ranged from 0.2 to 1.6 percent. In addition, 3,001,775 tons, or 1,204,710 cubic yards of waste has been moved and dumped. The ratio of cubic yards of waste moved to tons of ore moved is 0.71 to 1.

DRILLING AND BLASTING

Drilling equipment consists of two 29-T Bucyrus-Erie gasoline-driven churn drills, 2 Gardner-Denver wagon drills, one Ingersol-Rand wagon drill, 8 jack hammers, and 3 portable, Diesel-powered, Ingersol-Rand air compressors, two of which are rated at 500 cubic feet and one at 315 cubic feet per minute.

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[5] Copy of Kaiser Co., Inc., monthly development map for January 1947, furnished by Ken B. Powell, mining engineer.

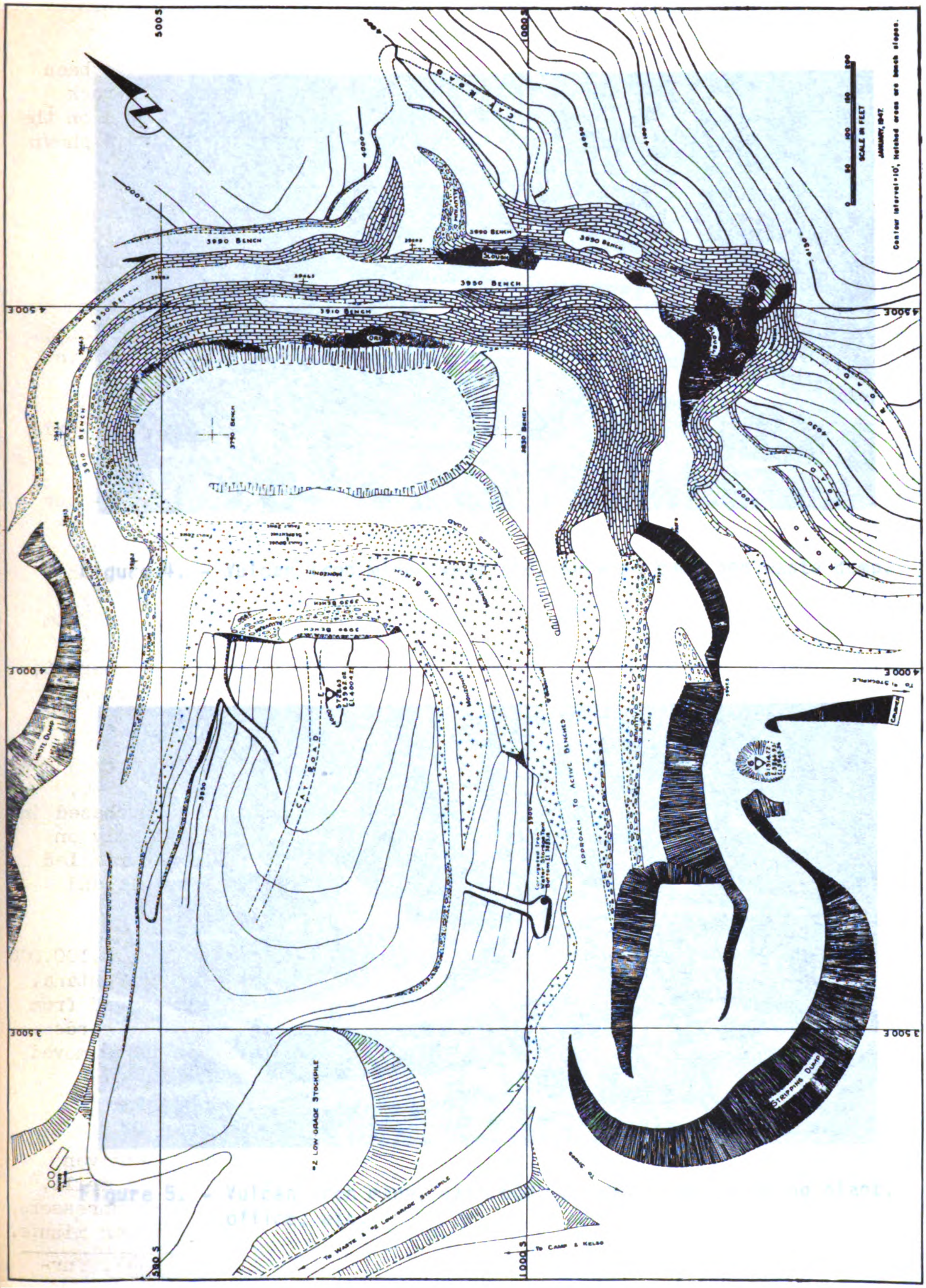

FIGURE 3. PIT PLAN, VULCAN IRON MINE, SAN BERNARDINO COUNTY, CALIFORNIA.

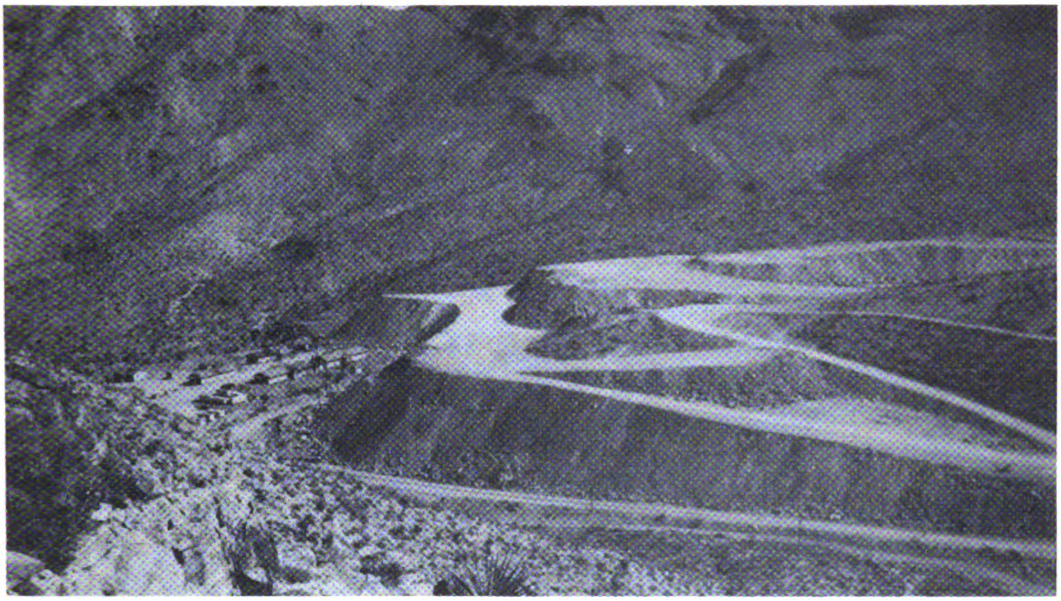

Figure 4. - Vulcan iron mine, west end, showing camp and waste dump.

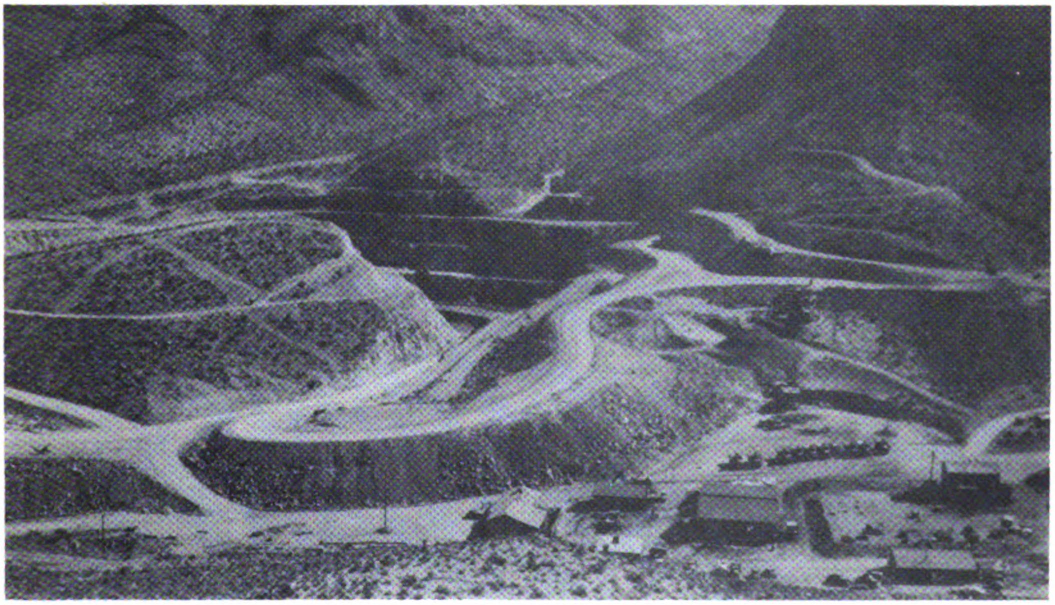

Figure 5. - Vulcan iron mine, east end, showing pit, crushing plant, office, etc.

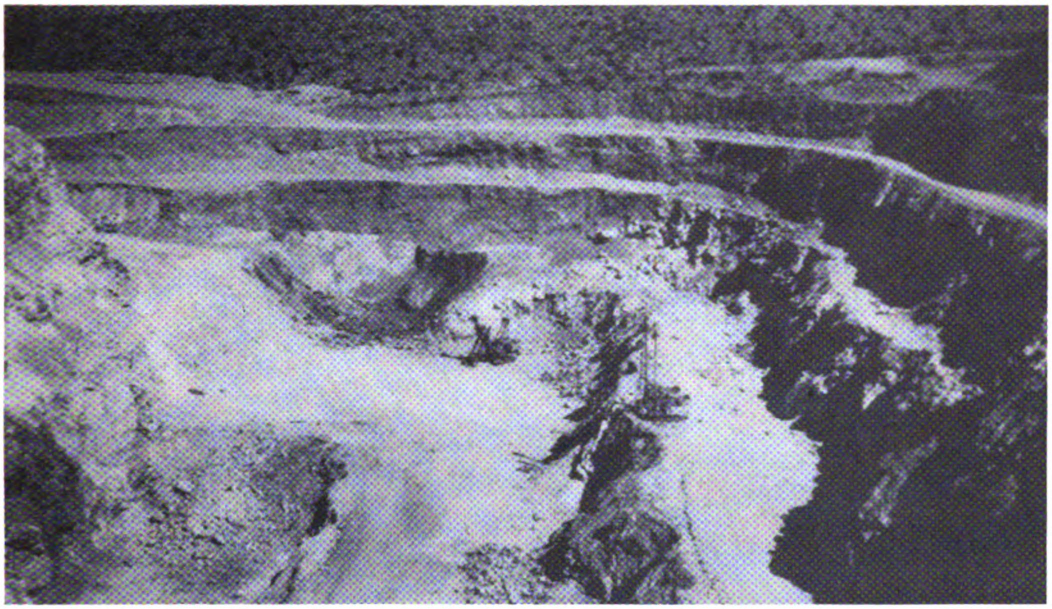

Figure 6. - View of pit, looking northwest from 4,000-foot bench.

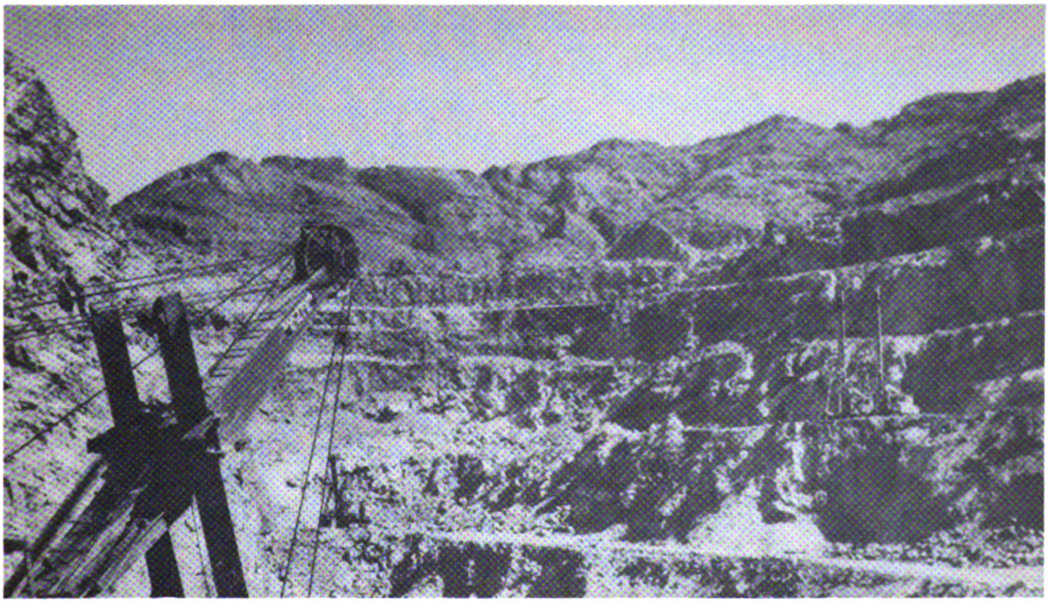

Figure 7. - View from bottom of pit, 3,830-foot level, looking N. 30° W.

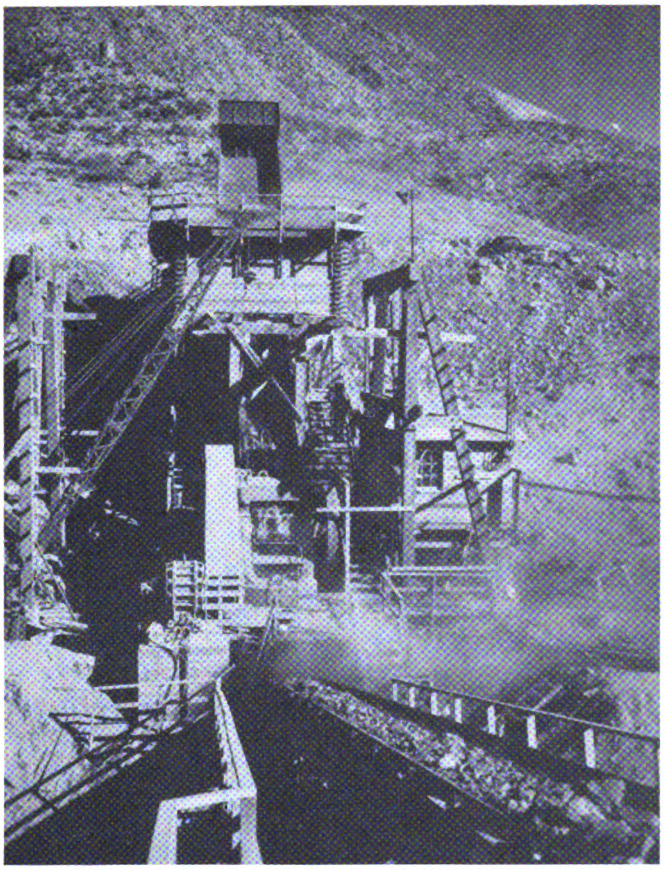

Figure 8. - Crushing plant.

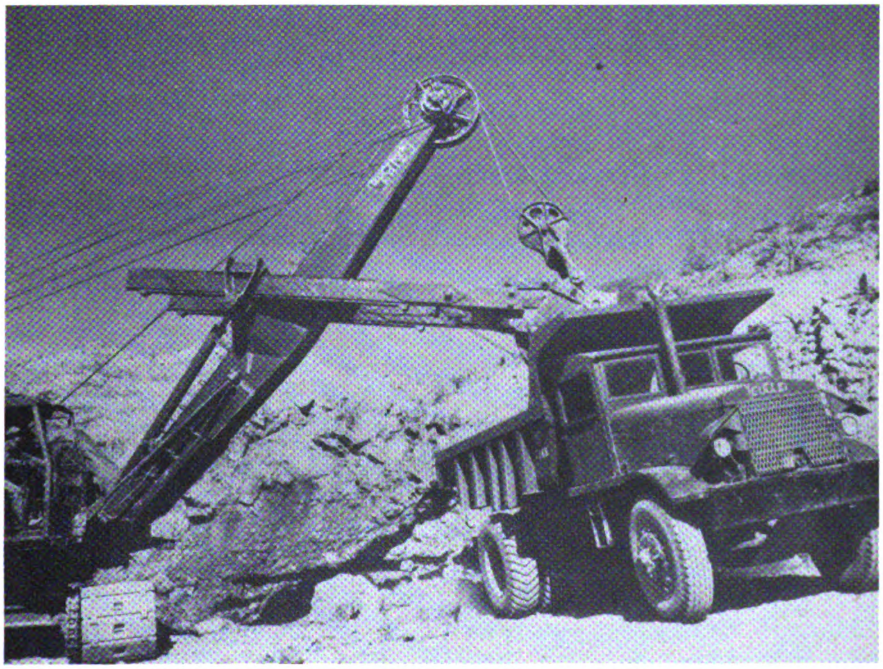

Figure 9. - Shovel in operation.

Each of the three types of drills has its special use. The jack hammers are used in drilling for secondary blasting to depths of 12 feet or less, and holes are spaced 3 to $3\frac{1}{2}$ feet apart. Wagon drills are used for drilling high bottom and drop cuts with holes 12 to 24 feet deep. Holes are spaced 6 feet apart, and a $3\frac{1}{2}$ inch starter bit is used. Churn drills are used for drilling blast holes on the benches, and holes are 24 to 55 feet deep, have a 13-foot burden and 13-foot spacing, and are 9 inches in diameter. (Figs. 6 and 7.) Churn-drilling holes less than 24 feet in depth is not economical. All holes on the benches are drilled 5 feet below ground level of the lower benches.

Jack-hammer holes are loaded and tamped in the regular manner. Wagon-drill holes are sprung two or three times to make room for a large charge, but churn-drill holes are not sprung. Holes are charged with 40-percent gelatin and then fired electrically with primacord, 2 or 3 sticks of 60 to 80 percent dynamite being used as primers. All calculations for the blasting charges are made by the powder foreman, and the charges, depending on the ground, vary as much as 300 pounds per hole. In some blasts as much as 10 tons of powder is used and 30 to 40 thousand tons of ore is broken. Powder consumption per ton of waste broken is 0.251 pound, and per ton of ore it is 0.335 pound.

ORE HANDLING

After the ore or waste is broken, it is handled by two 54-B, Bucyrus-Erie, $2\frac{1}{2}$ cubic yard, Diesel-powered shovels, and one shovel of the same type is held in reserve. (See figs. 6 and 7.) The shovels load into 10 cubic yard-capacity Euclid dump trucks, 11 of which are required. One shovel will load 18.6 trucks per hour. (See fig. 9.) The distance from the pit to the crushing plant has varied from 350 feet to 2,400 feet. The crushing plant, as shown in figures 5 and 6, is near the southeast end of the pit.

The trucks dump into a bin, from which the ore is fed to a 6-inch bar grizzly by a 5-foot Stephens-Adamson pan feeder. A 42-inch, 10-ply, stacker conveyor belt receives the undersize, and the oversize is reduced to 8 inches by an electrically driven, 42- by 48-inch, Taylor jaw crusher having a capacity of 3,000 tons per 8 hours. The product from the crusher goes to the stacker belt, which feeds the storage pile, where 6,000 tons of ore can be stocked. The stock pile is above an inverted con-shaped cavity cut from the rock and connected with an adit where a 5-inch Stephens-Adamson pan feeder discharges to a 42-inch conveyor belt equipped with a Merrick weightometer. Trucks loaded direct from the belt haul the ore to Kelso.

Kelso is 9 miles by road from the mine, and the grade, with a maximum of 6.9 percent, favors the load. Kenworth semitrailer trucks of 15 cubic yards capacity are used for haulage, all of which is done by contract. The average load is 25 tons of ore. Trailers are end-dump type with hoist attachment, and the trucks are powered with Cummings Diesel engines and equippe with hydrotarders. A hydrotarder is a braking mechanism attached to the drive shaft of the truck. It has a closed water circuit, the circulation of which can be regulated from the driver's seat to hold the truck at any desired speed on downgrade. With the mechanism, speeds commensurate with the condition of the road surface can be maintained on steep downgrades with no danger of the truck gaining speed or going out of control, and with no undue strain to the clutch or engine. Braking is attained without the use of brakes. These make for fast runs with loads to Kelso.

The road is 22 feet wide and was built by removing all the large boulders from the road bed, smoothing with a blade, and laying a 3-inch, blacktop, road-mix, macadam surface cover, in which the minus $1\frac{1}{2}$-inch material from the sides of the road bed was used. More than 1,900,000 tons of ore has been transported, and the road maintenance has been negligible despite the great variation in temperature.

At Kelso the ore is dumped from a ramp into a 100-ton bin, from under which a pan feeder discharges onto a 42-inch belt conveyor equipped with a Merrick weightometer. This belt discharges into the railroad cars. The grade of the railroad siding is 0.6 percent, and the cars are placed under the discharge belt by gravity. A Buda Diesel engine connected to a 60-kilowatt generator furnishes power to a pan feeder, loading belt, and an electric, vertical, capstan-type car puller, which is used to start the loaded cars down the spur. When more ore is trucked than is required for shipment, the excess is stock-piled at the railroad loading ramp. The ore is transported to Fontana by the Union Pacific and Santa Fe Railroads. The freight rate is $1.25 per ton for a minimum shipment of 1,500 long tons.

ORE TREATMENT

At Fontana the ore is dumped from the railroad cars by a Link-Belt car roll against baffle plates to a long-pan feeder. The feeder discharges to a 42-inch conveyor belt; which carries the ore to a jaw crusher, which reduces it to minus 4-inch size. The crusher discharges onto a 1-3/4-inch mesh screen. The oversize is fed to a cone crusher that works in closed circuit with the screen. The undersize product goes to another screen, usually of 3/4-inch mesh but occasionally of 3/8- or 1/2-inch mesh. The undersize goes directly to the sintering plant, and the oversize to the bedding system. Portions of the oversize can be diverted, when required, to regrinding cones and sent to the sintering plant. About 50 to 70 percent of the Vulcan ore is sintered because of its high sulfur content.

The ore is bedded longitudinally in piles from a traveling belt stacker. Four of these piles are laid parallel. The cross section of each is triangular. The ore is removed from the piles by recovery rakes and plows, which cut the pile crossways and dump onto a conveyor belt equipped with an automatic sampler and an automatic weigher. The belt discharges into one of the storage bins that supply the blast furnace. The furnace operators have complete analysis of ore, which is generally charged into the furnace within 2 days after the filling of the storage bins and can balance the charge accordingly.

The sintered ore, when cooled, is stocked in a storage pile by an elevated conveyor belt with movable tripper. It is drawn off through chutes

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to a recovery belt in a tunnel beneath the pile and transported to the blast-furnace bins, sampled, and weighed out for charge, the same as the ore.

SAMPLING

Only rough sampling of the ore is done at the mine. The approximate grade is known from the diamond-drill analysis, and the sludges from the churn-drill holes for blasting are sampled and analysed as a further check on the grade of ore in the benches being worked. A limited amount of selecting is done by the shovel operators, and any considerable amounts of serpentine or limestone are sent to the waste dumps. The conclusive sampling is done at Fontana by an automatic sampler on the conveyor belt to the blast-furnace storage bins.

MINE SURFACE PLANT

In addition to the crushing plant, the installations at the mine consist of an office and warehouse, garage, gasoline pumps, machine shop, power plant, 2 dormitories, cook house and mess hall, cook's dormitory, and the superintendent's house. At Kelso, a trailer court was built to accommodate 20 families in company-owned trailers, and space was provided for 10 private trailers. The normal complement of men, including the kitchen staff, is 80 to 85 and 12 to 14 on the contract truck haul.

The power plant consists of a Fairbanks-Morse 280-horsepower, 4-cycle, marine-type, Diesel engine, direct-connected to a Fairbanks-Morse generator. This plant furnishes power for crushing, conveyor belts, shop equipment, lighting, and refrigeration.

PRODUCTION DATA

Churn drills average 6.22 feet of hole per hour, and the wagon drills average 16.42 feet per hour.

Shovels average 342 short tons of ore or waste per hour.

Average man hours per ton ore and waste is 0.157.

Tons of ore and waste per man shift, including all personnel at the mine, averages 50.96.

An average of 18.6 trucks are loaded per shovel hour.

Powder consumption per ton averages 0.335 pound for ore and 0.251 pound for waste.

Gasoline consumption averages 0.055 gallon per ton of ore and waste hauled.

Diesel oil averages 0.3 gallon per ton of ore and waste hauled.